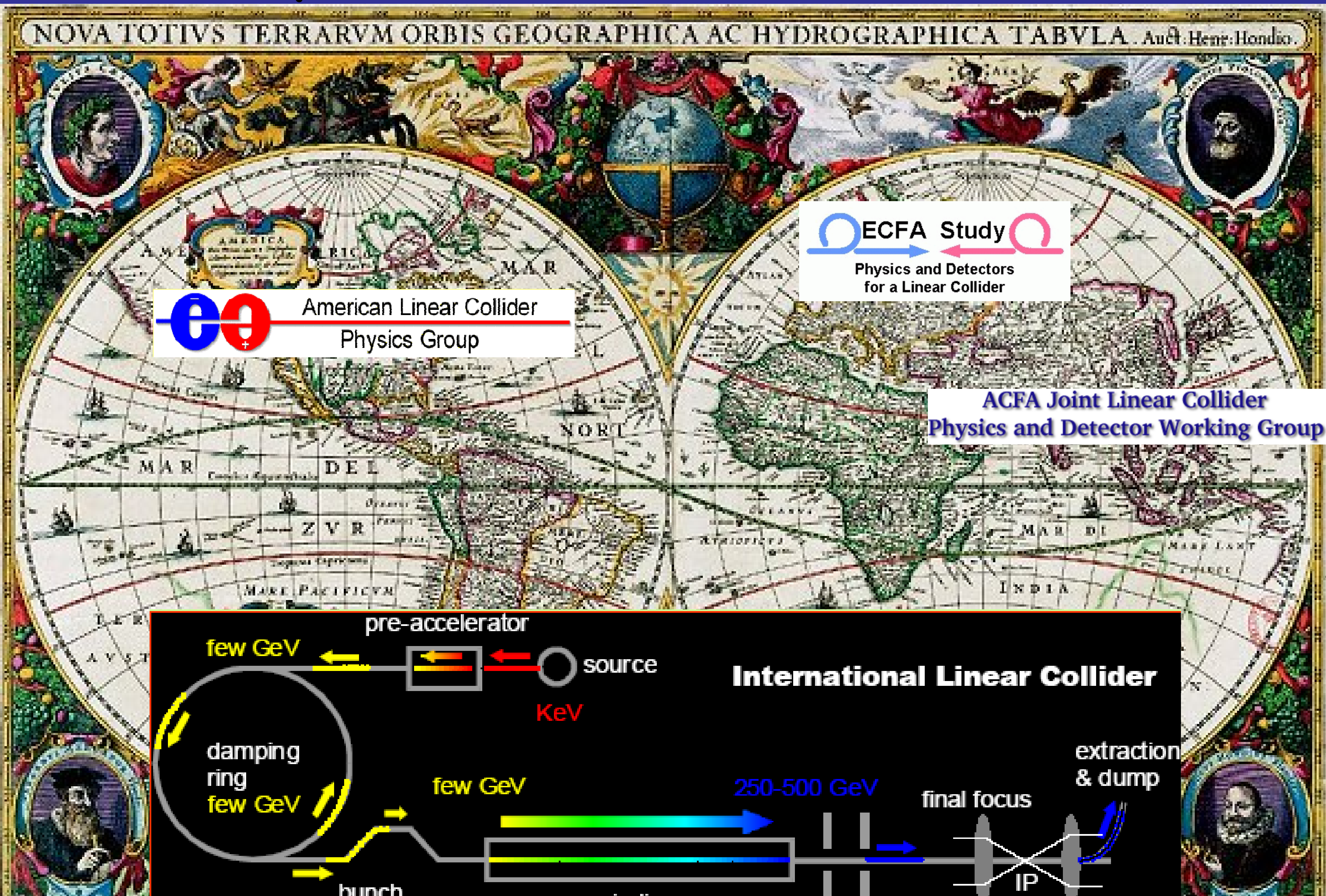
ILC: Physics and Politics issues



Purpose of this presentation

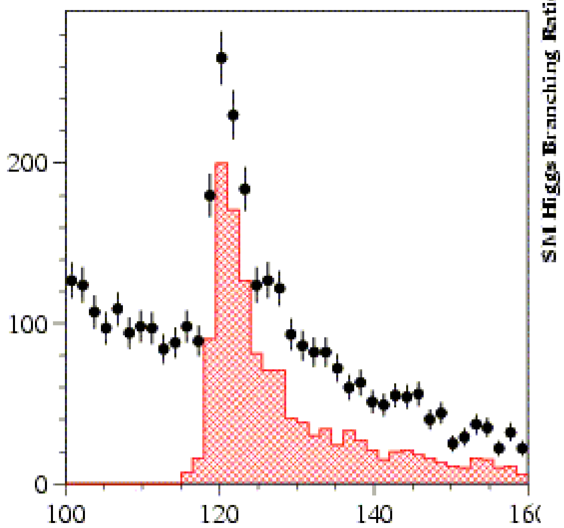
- Mainly on physics issues, focused on the SUSY scenario
- Few aspects of the detector and the machine
- Overview on the strategy

Physics at ILC

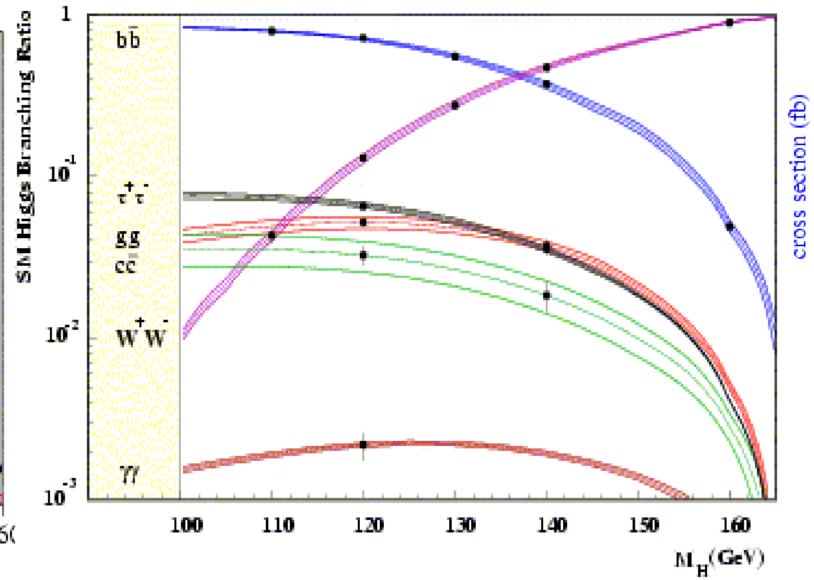
3 topics:

- EWSB: Higgs + ttbar, requires ILC up to 1 TeV with high L, very well covered by past studies (1 TeV needed on the S.I. scenario)
- SUSY: best scenario so far but not sure to 'exist' that is to be seen at LHC/ILC
- PM which allow in some cases to reach mass scales well beyond LHC/LC

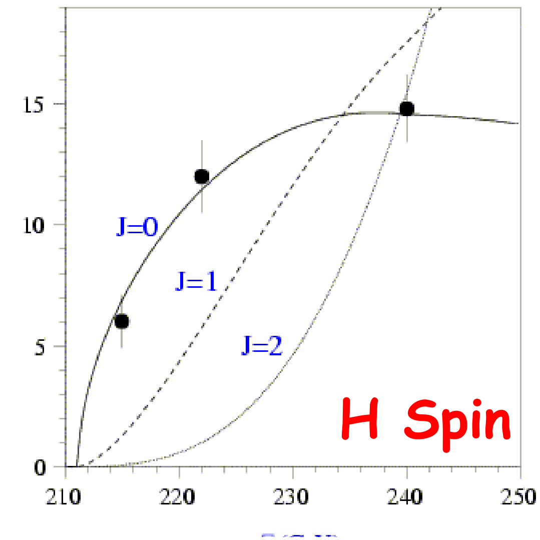
ILC Physics in SM

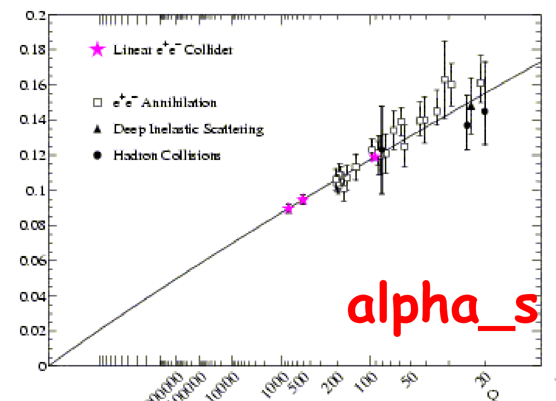


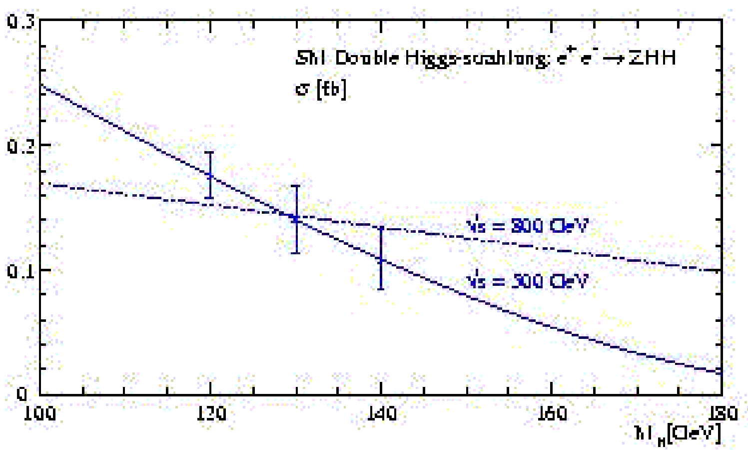
Inclusive Higgs:
Z Recoil mass



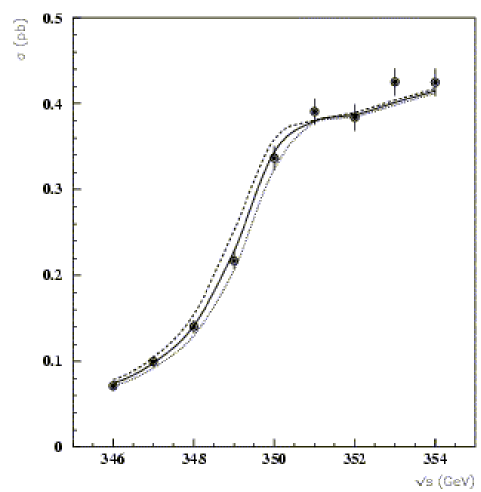
H Branching Ratios



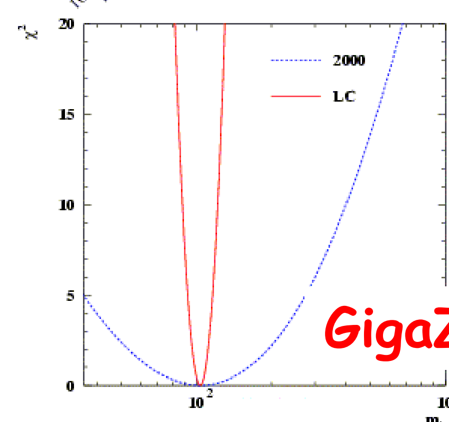




ZHH



Top quark mass



... and much much more

SCOPE of the ILC

- Set by the physics
- 500 GeV phase to study Higgs+top+PM cumulating 500 fb-1 in ~6 y
- ~1 TeV phase to reach ~1 ab-1 needed e.g. for Zhh, to extend the reach of discoveries, to cover the SI scenario (WL-WL) if needed
- Options:

  e+ polarized needed for GigaZ

  $\gamma\gamma$ γe e-e-

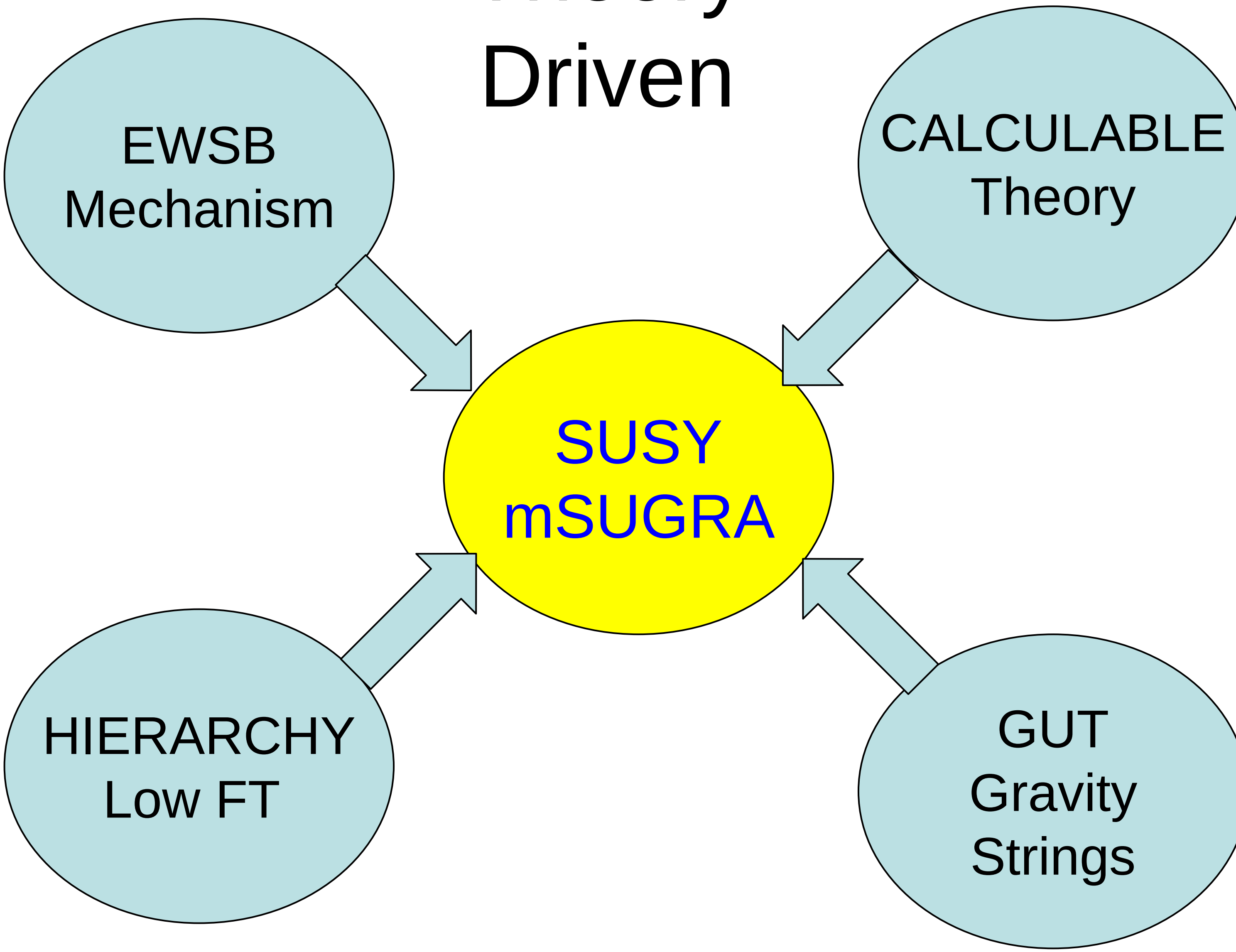
SUSY

- At present the only ~ satisfactory extension of SM but no solid predictions on masses
- LHC/LC benchmarks studied within mSUGRA
- Several issues related to flavor and CPV, require different schemes ‘protecting flavor’

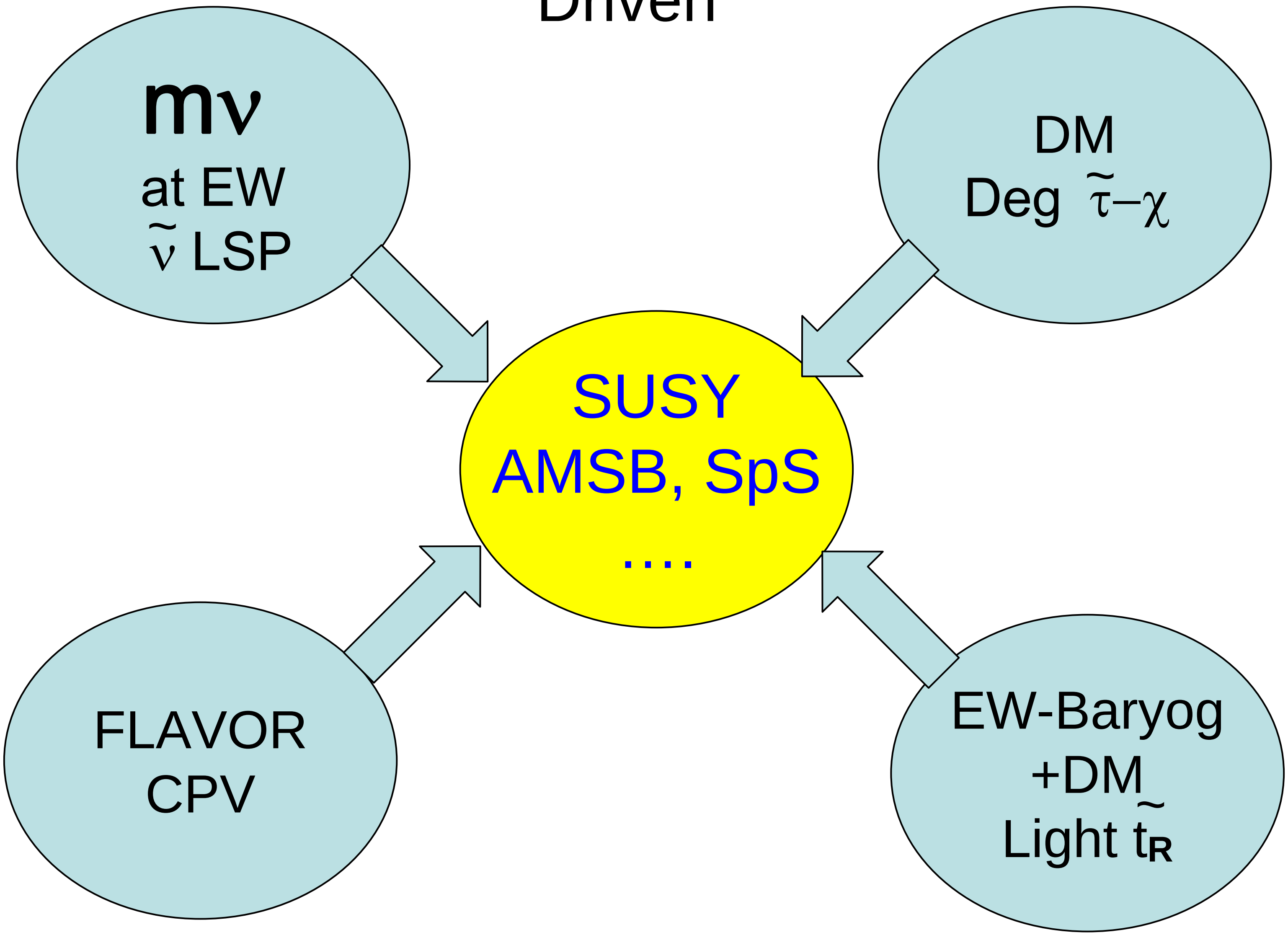
  Gauge/Gaugino –mediated, SpS, AMSB
- DM plays a central role (also the gravitino pb)-> connection to cosmology

-> Various schemes proposed either ‘top-down’ or bottom-up’ or some mixture

Theory Driven



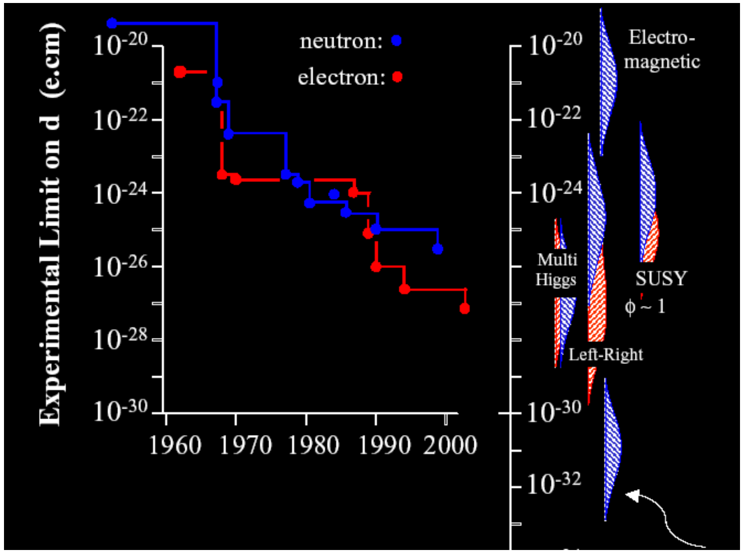
Phenomenology Driven



CPV and SUSY

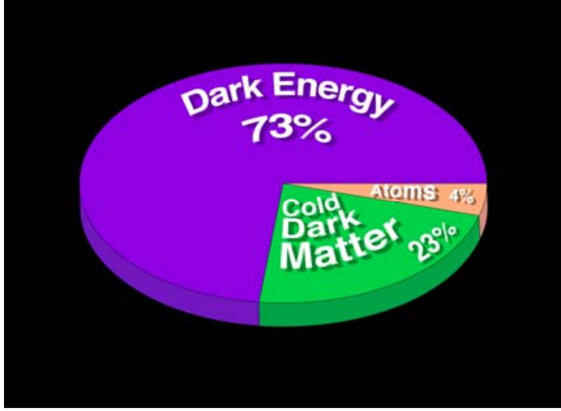
Two usual ways to satisfy flavor and CPV issues:

- Complete decoupling from flavor like AMSB
  Very heavy gravitinos (no reheating issues)
  Light sleptons (g-2 OK, ν sector without see-saw)
- Send all scalars to very high masses like SpS
  Keeps the 'good part' of SUSY
  GUT, neutralino LSP
  CPV signals expected
  Highly FT but Nature also !



Model/ Observable	SpS	AMSB	$\tilde{\nu}_R$
LSP	Higgsino	Wino	$\tilde{\nu}$
G-2	No	Yes	Yes
CPV	Yes	No	?
Higgs	170 GeV	Fat Higgs	
LHC	Not certain (Gluino)	Not certain (LSP 2 TeV)	Confusing
ν	See-saw ?	Dirac	Majorana

As an example: the DM issue



- DM constrains severely SUSY
- There are 3 types of scenarios:

- The LSP is a Bino, hard to annihilate

-> either very light sleptons or sleptons degenerate in mass (< 10 GeV) with LSP

- The LSP has a Higgsino component (low μ) sleptons very heavy SpS
- The LSP is a Wino AMSB. To saturate WMAP, the LSP has to be 2 TeV

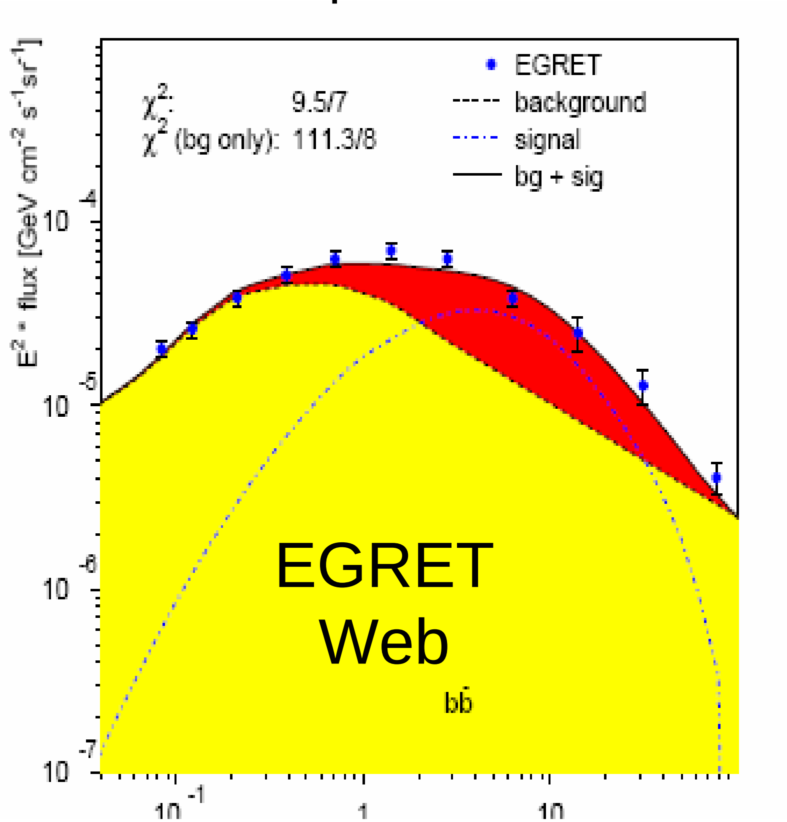
Has DM being discovered ?!

- Several indications

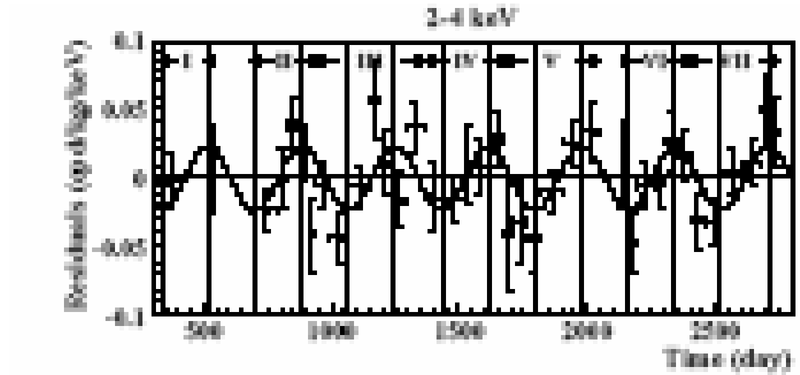
  Direct detection > 6 sd in DAMA

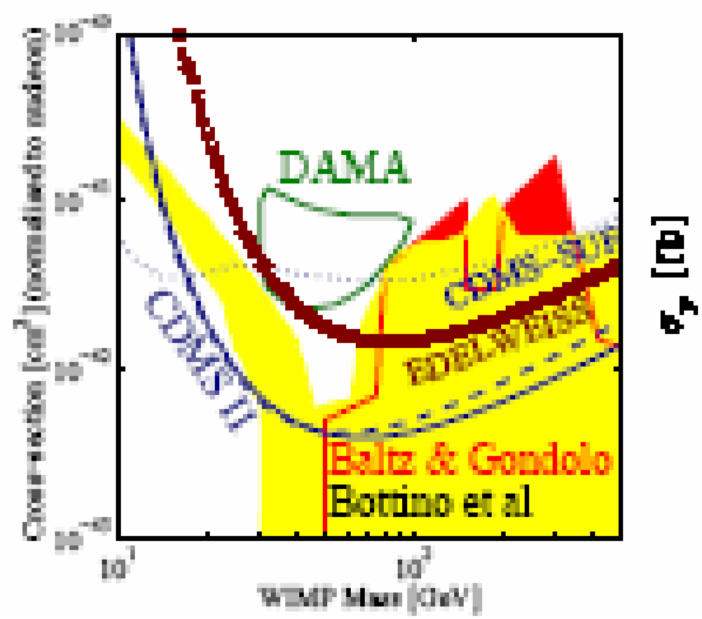
  Indirect excess reported in EGRET, HEAT
- Cannot be certain that they have common origin (modeling, reduced observables)
- Lesson (P. Gondolo,G. Kane): we will need LHC/ILC to be sure of the interpretation and generate a proper cosmological modeling
- We will need ILC to be precise enough to match Planck precision and make sure that there is a significant coincidence

Astro-ph/0408272

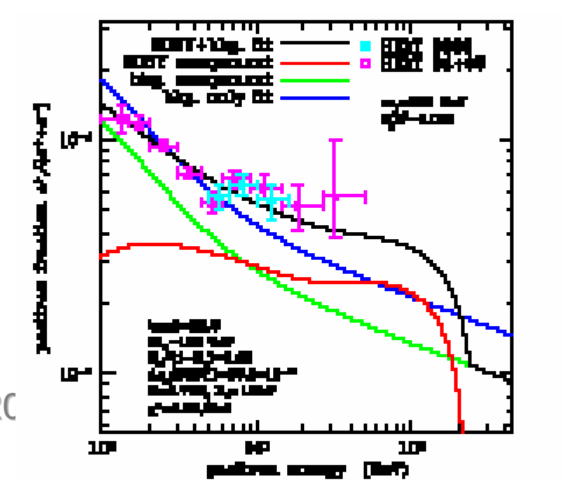


Direct: DAMA



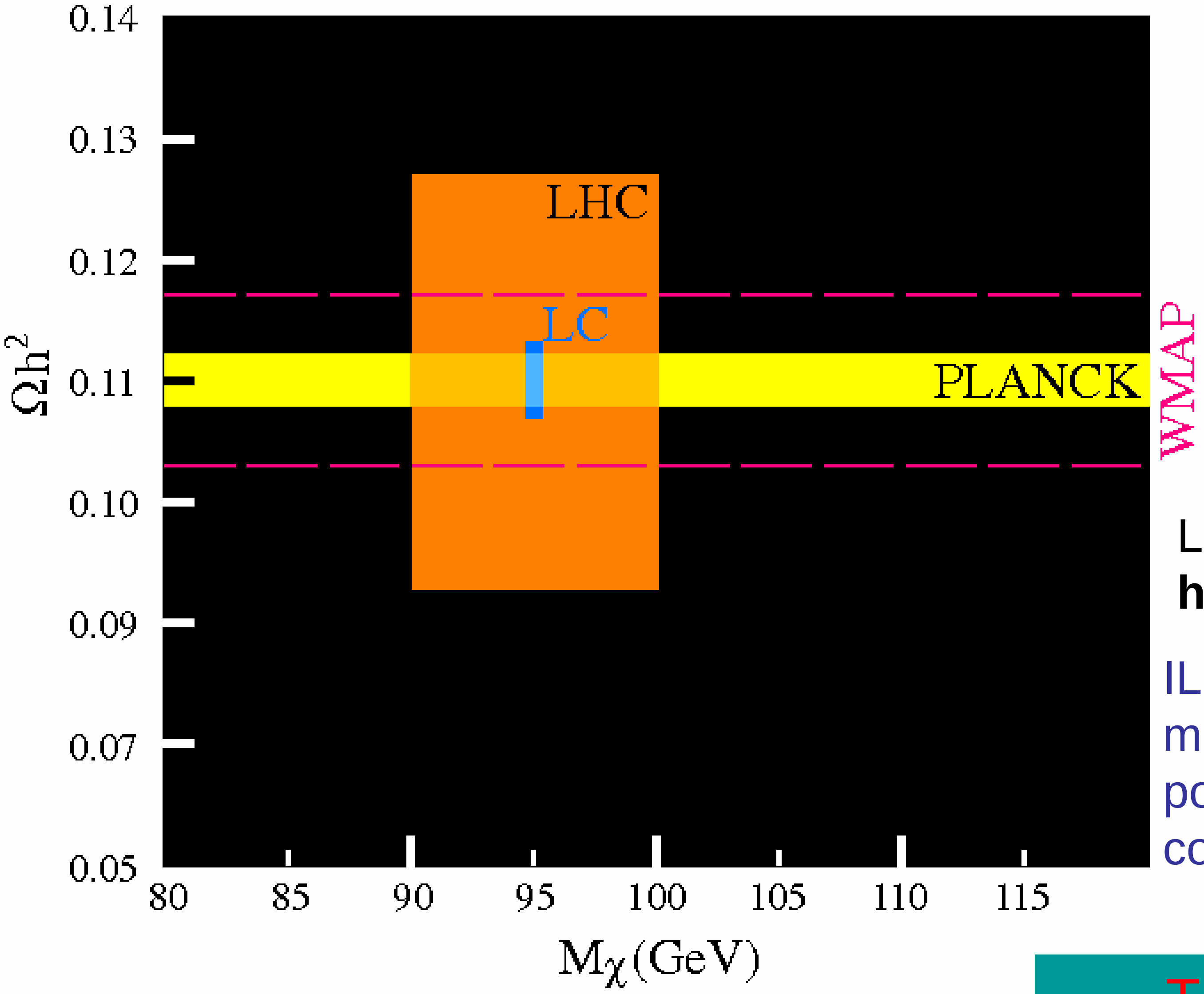


HEAT
e+



Nuclear Spin dependence ?

Colliders and Cosmology



MicrOMEGAs Pt B

'WMAP'	7 %
LHC	~15 %
'Planck'	~2 %
CL	~3 %

LHC pt B: Battaglia et al
hep-ph/0306219

ILC: precision similar for most other co-annihil. points A C D G I L consistent with WMAP

Theory: could be a limiting factor

Complementarities

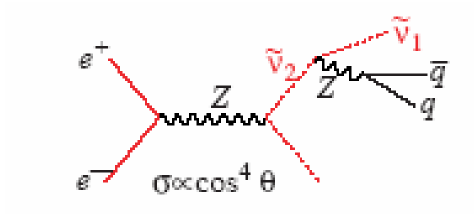
- The DM example illustrates how ILC can contribute to the DM issue in cosmology
- Similarly, If SUSY is the correct theory,

  it can also:

  - Explain Baryogenesis provided that there are light $\tilde{t}_1$ +chargino and extra phases
  - Provide a mechanism to give masses to neutrinos

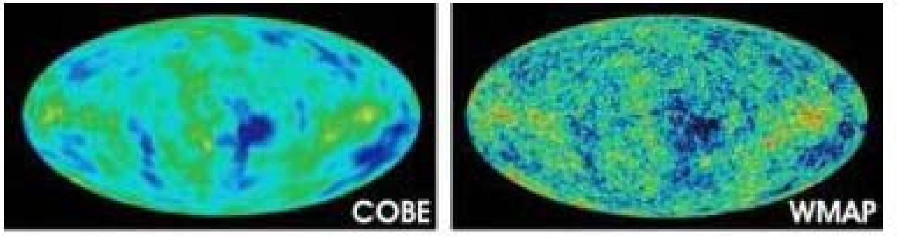
In both cases one needs

the ILC to investigate the scenario



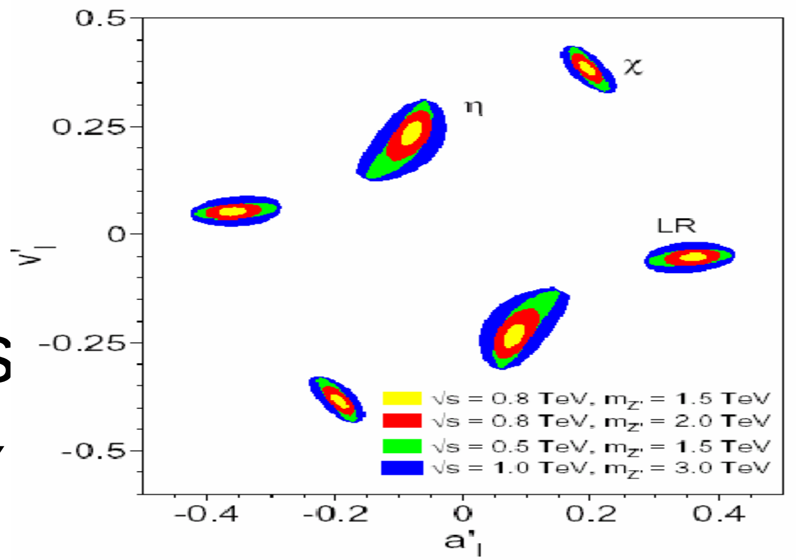
H. Murayama

Precision measurements @ILC



- e.g. (MH)Direct≠(MH)Indirect±5 GeV ?
  -> New physics is present
- Which type of new physics ?
- Which new mass scale ?
- ILC provides several precise observables to provide an answer
- Take an example: a Z’

The Z' scenario



- Expected in a large class of models, including SUSY (origin of μ in $\mu H_u H_d$ pb)
- Indirect detection with high precision ILC allows to go to ~10 TeV and also
- ILC essential to identify the type of Z'

-> Define future machines (CLIC, VLHC)

LHC :

- up to ~5 TeV direct observation

- up to ~2 TeV identif.

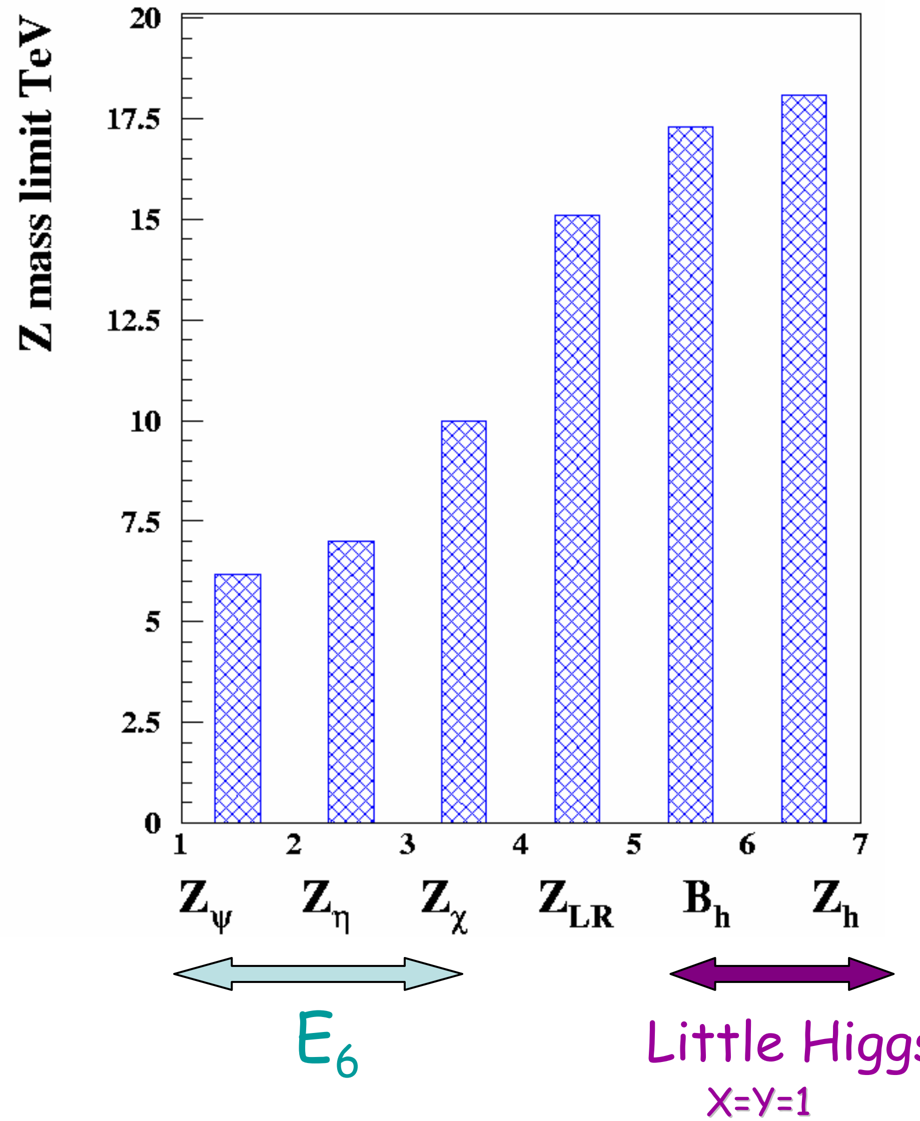
LC :

- discriminate between models up to ≥ 5 TeV

- predict MZ′ with a relative accuracy

< (MZ′/10TeV)²

< 25 % at 5 TeV



1 TeV 1 ab-1

Possible scenarios at LHC with the consequences on TeV LC called TLC (and on CLIC)

Scenario	Models	GigaZ at TLC	TLC below 500 GeV	High Energy TLC	LHC	From LHC to CLIC (or SLHC)
Light Higgs alone	SM	Quantum Test (QT) ΔM_H=5 GeV > SM ?	Spin/Parity BR(fermions,g/γ,W*W) ZZH and WWH couplings	ZHH 10% ttH <10% anomalous W/Z couplings	~10 times less precise, less BR's no spin/parity ~ no ZHH	Not motivated (SLHC for ZHH)
Light Higgs +SUSY	MSSM	Stop mass,A_t	Indirect mA, mH	Same+A,H,$H^{\pm}$	Same	Heavier Higgses
	Invisible H	Full info available	Same except WWH	Heavy Higgses (e.g. into $\chi^{\pm}$)	Difficult, no Higgs mass information	Heavier Higges
	NMSSM	QT	ZZH reduced	Heavy Higgses	More Difficult	Heavier Higgses
Heavy Higgs	SM	QT If mH< 300 GeV: Room for Physics beyond SM ?	ZZH, WWH up to 400 GeV	Higgs up to ~0.8 TeV anomalous W/Z couplings	Confirm SM but loweraccuracy no QT info	Not Motivated
	Fat Higgs (SUSY)	QT (A,H,$H^{\pm}$ isospin violation effects)	Idem	Same+additional Higgses A,H,$H^{\pm}$	Ambiguous unless A,H,$H^{\pm}$ identified	Heavier Higgses
	Little Higgs	QT Z-Z' mix for Z' up to 7 TeV	Idem	Z' up to 15 TeV Effect on ZWW	Z' up to ~5 TeV Ambiguous	Not motivated if Z' not seen at LHC (SLHC motivated Z')
	ND>4 ADD	QT Z-Z' mix for Z' up to 13 TeV	Idem	Z' up to 20 TeV	Z' up to ~5 TeV Ambiguous	Not motivated if Z' not seen at LHC (as above for Z')
	ND>4 UED	ρ effect isospin violation for KK masses <1 TeV	Idem	Pair production of KK excitations	KK signals similar to SUSY	CLIC extends LHC/LC mass range
No Higgs	Strong Int.	QT -> Constraints on theory > SM	WLWL >3 σ larger with resonance	WLWL >6σ larger with resonance	>5σ	Direct observation of ρ-resonance(?)
	Higgless ND>4	QT -> Constraints on theory		Z' visible ZWW anomaly	Observation of Z' but ambiguous	Z' on shell at CLIC

Detector

In many instances LC analyses will be systematics limited

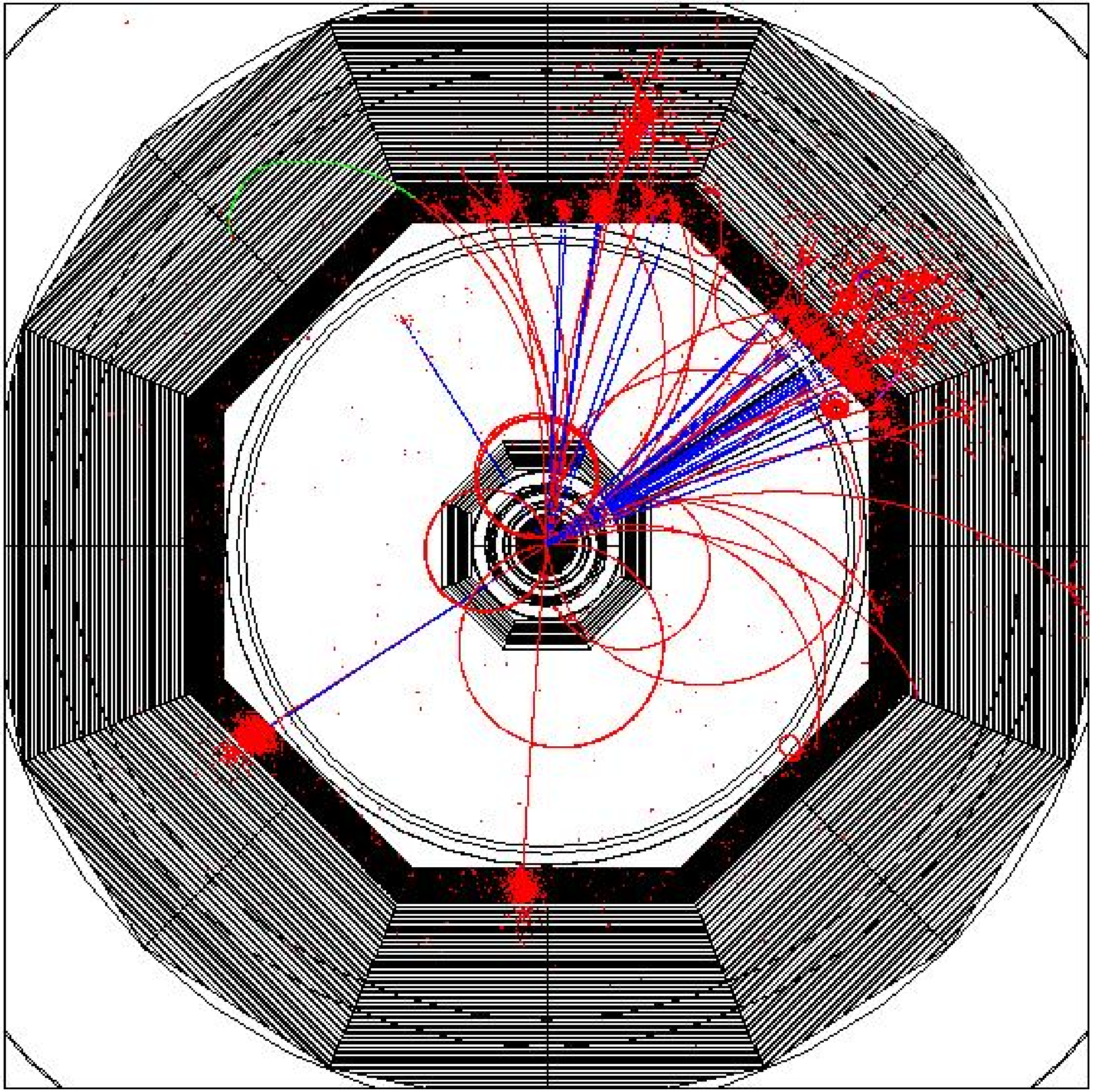
3 outstanding improvements/LEP-SLD can be fulfilled on the detectors:

- Improved vertexing : c (ε=70% >80% pure),tau tagging
- Improved E-Flow : 6/8 jets WW/ZZ$\nu\nu$ $\delta E/E \sim 0.3/\sqrt{E}$
- $\delta p/p^2 \sim$ 1/10 LEP down to 100 mrad

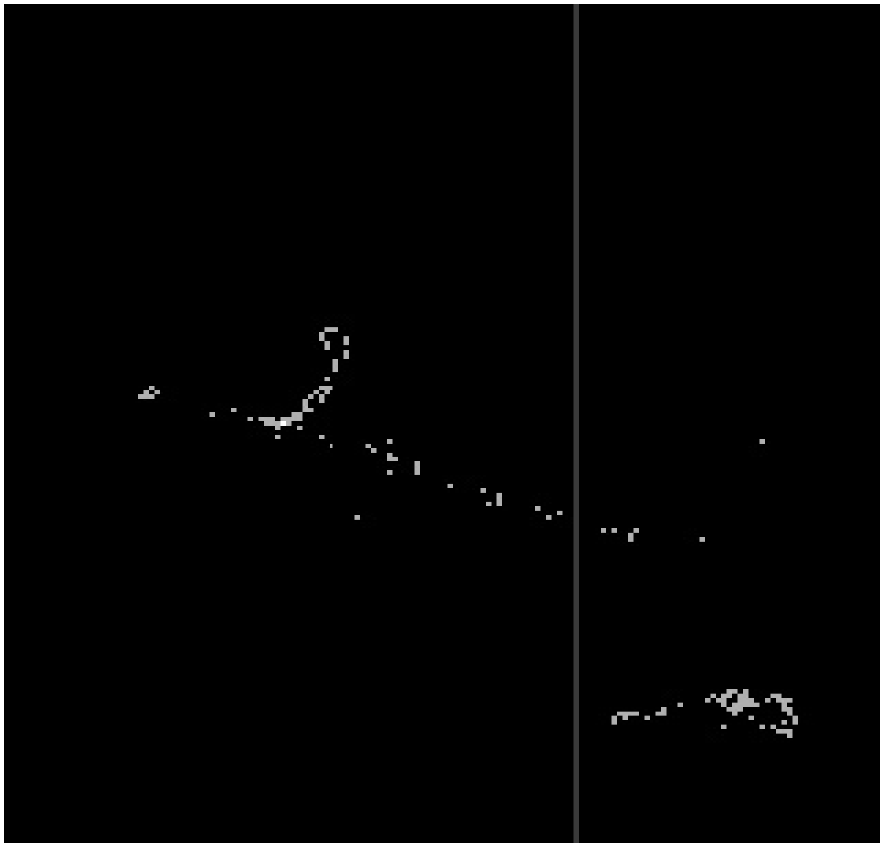
Also:

- Hermeticity on energetic γ/e down to 5 mrad
- $\Delta\mathcal{L}/\mathcal{L}$ to 10^{-4} + Polar + $\sqrt{s}$ to 1 MeV for Z physics

-> Machine Detector interface

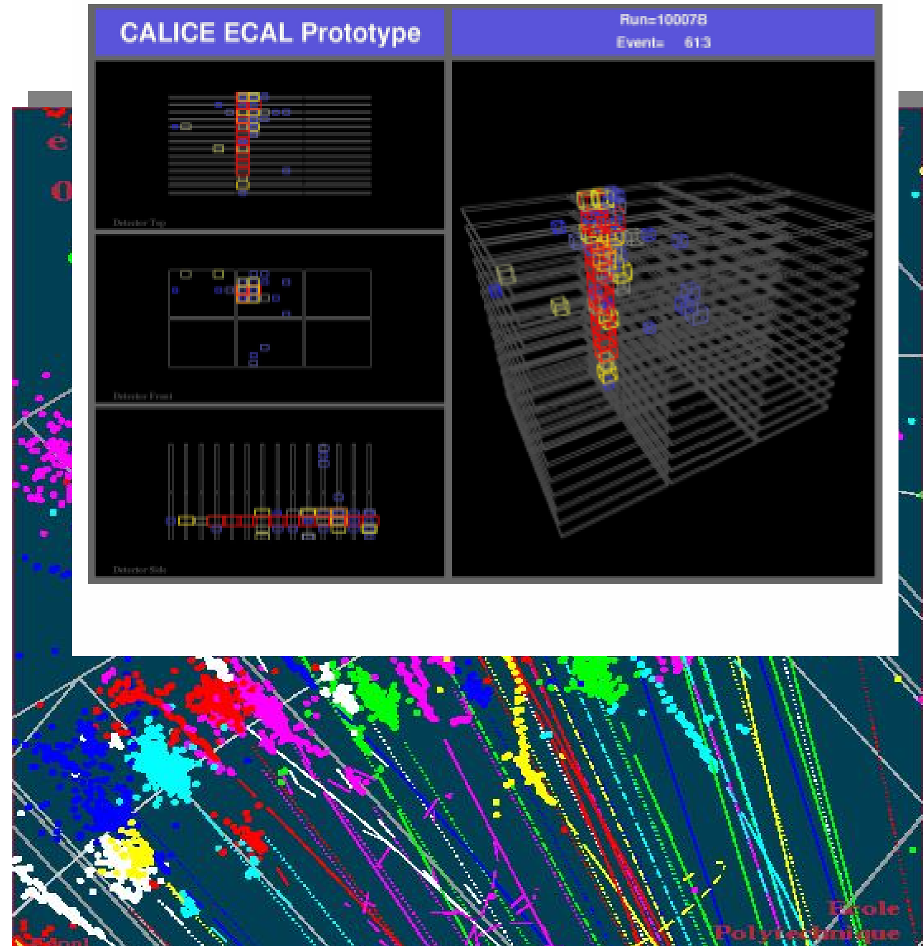


Towards a bubble chamber pattern ?



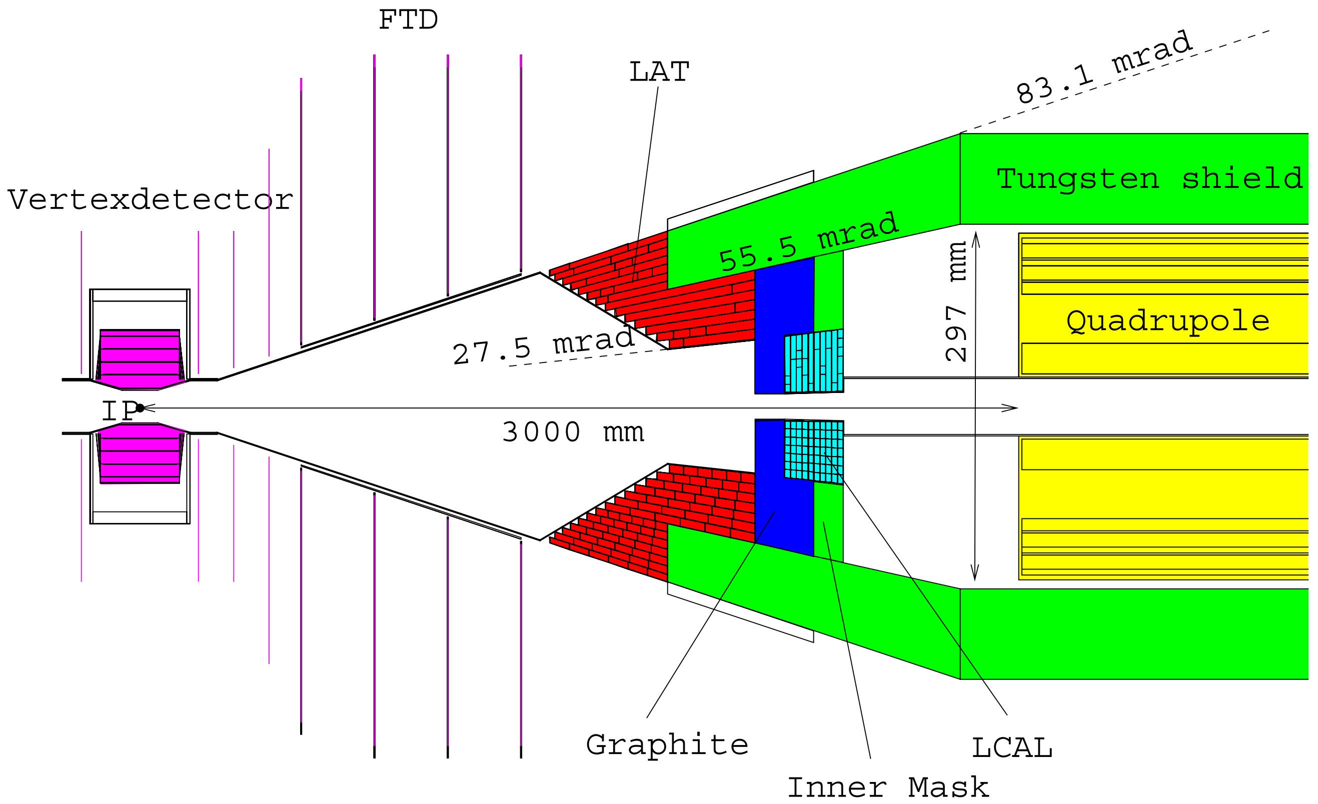
5 cm

Pixelized TPC



Calorimetry with high granularity

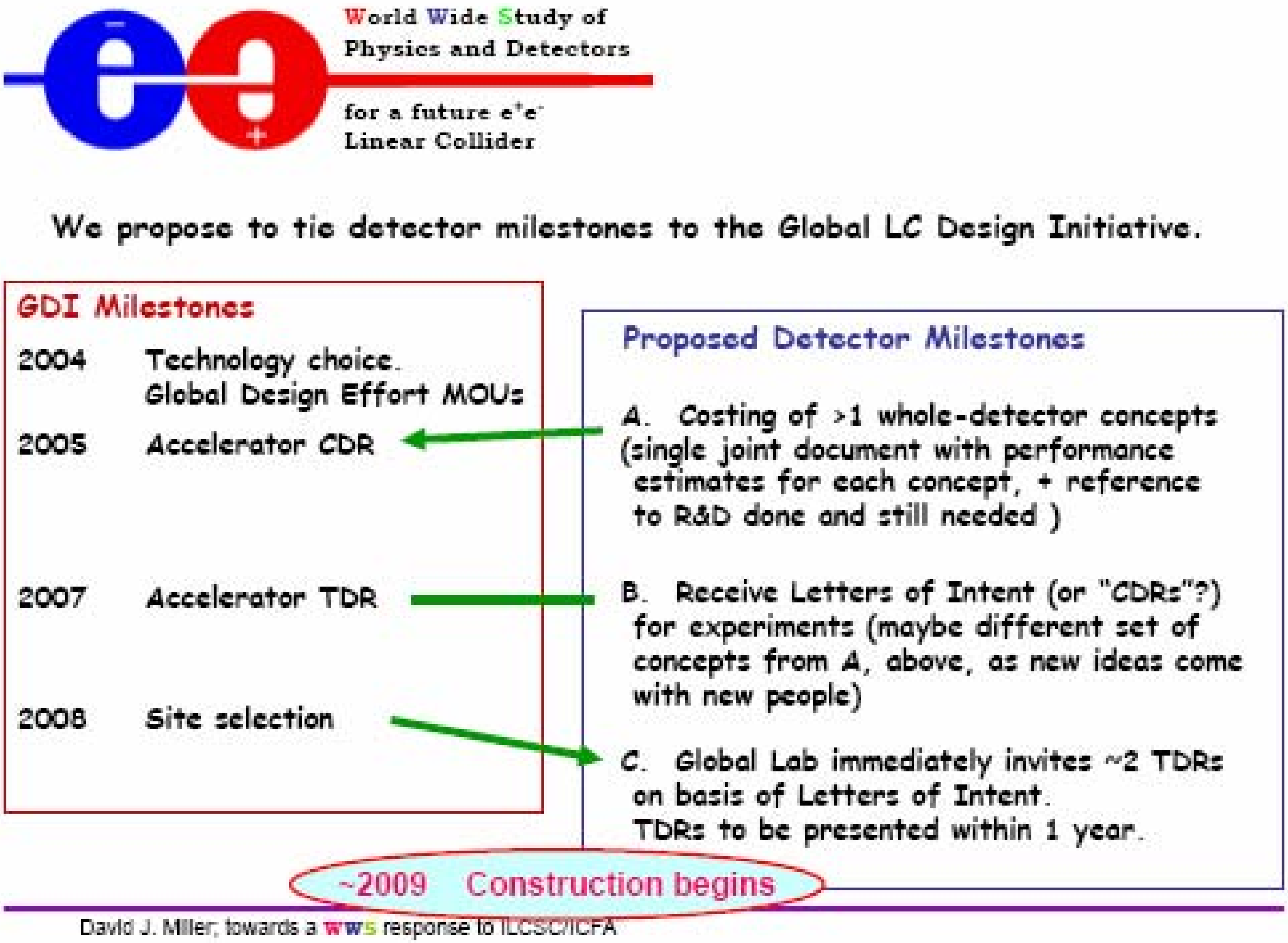
Forward Hermeticity down to 5 mrad



What is happening in the world?

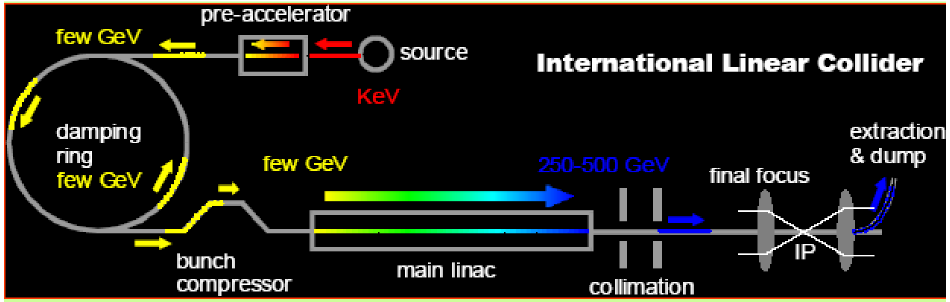
- 3 concepts of detectors are discussed, one is ~TESLA TDR, one with a Si tracker in the US, one considering a larger detector
- An international R&D panel is been set up to identify the priorities
- A CDR for the machine and a document for the detectors beginning of 2006
- LoI in ~2008 sent to the Global Lab
- 2 experimental areas are envisaged

Scenario defined at LCWS04



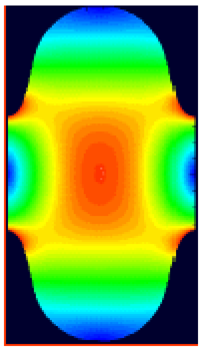
Critical items for the machine

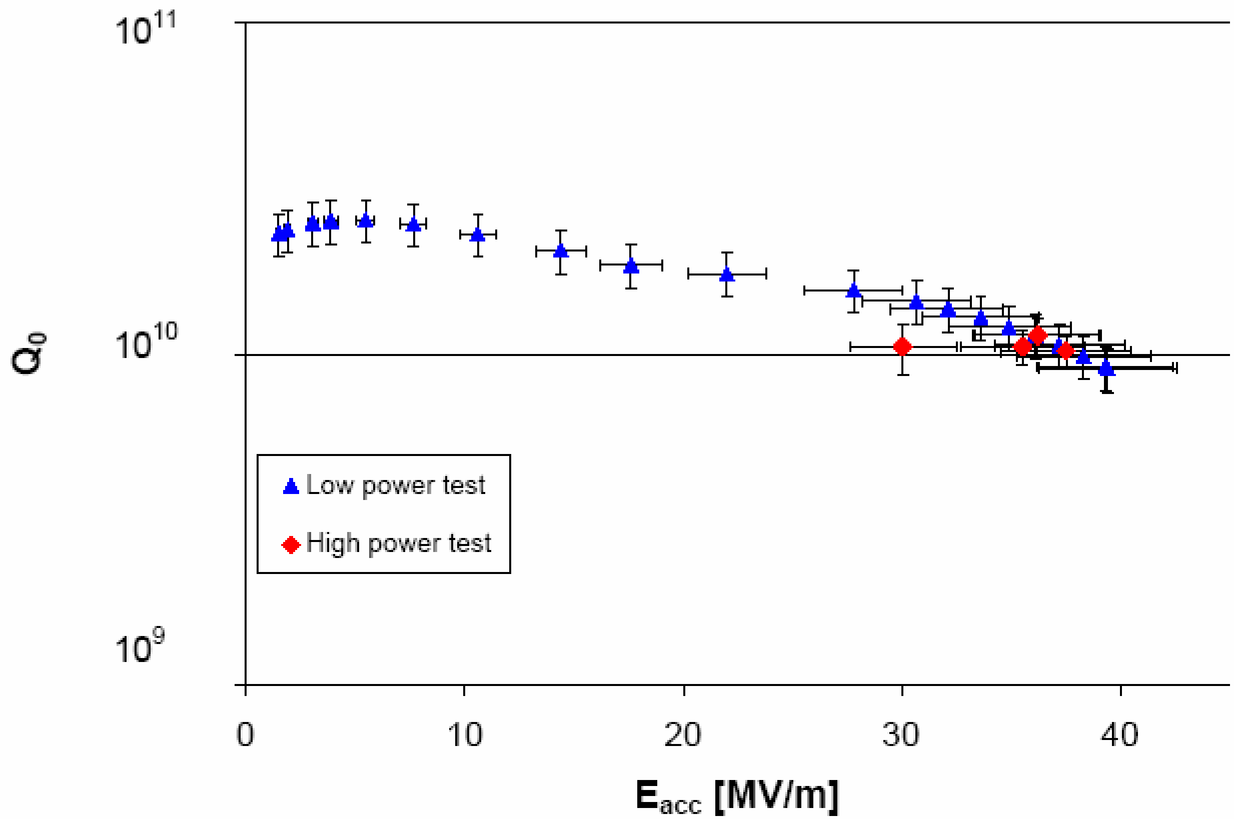
- Major investment (>80%) is on the SC Linac
- There are however many other issues e.g.
  - Polarized e-
  - Damping Rings
  - Generation of e+
  - Beam Delivery
  - ….



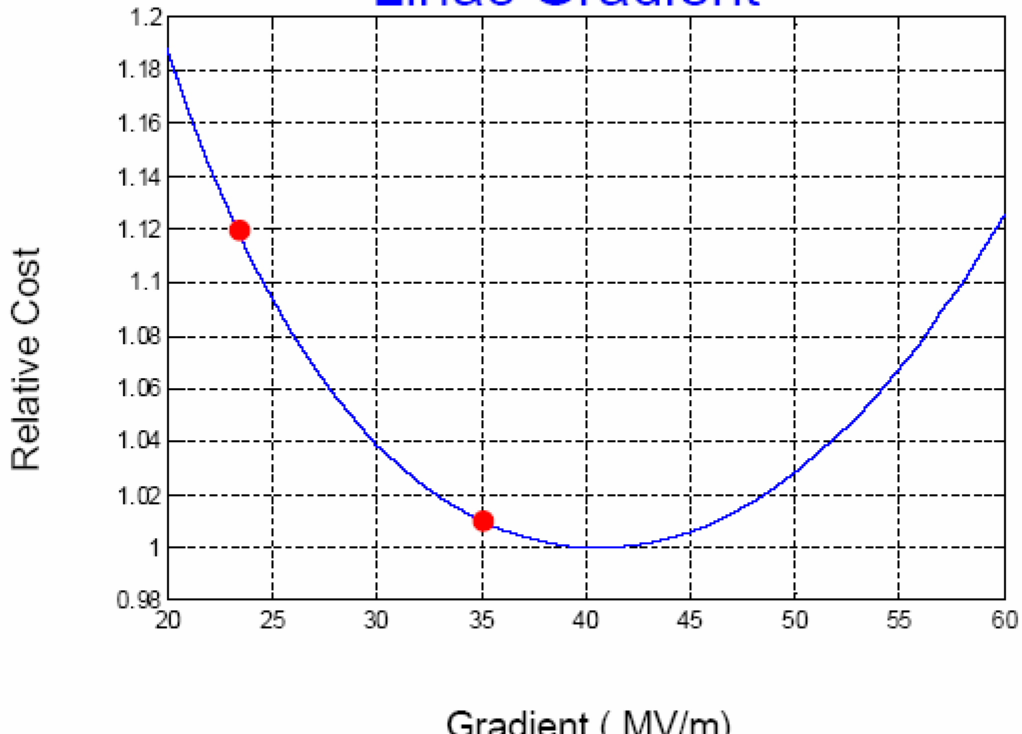
- The recommendation on technology allows to share the work among the 3 regions
- New evaluation after the TESLA TDR but one should avoid ‘reinventing the wheel’
- Needs leadership, coordination, identification of resources, sharing of the work -> GDE (global design effort°

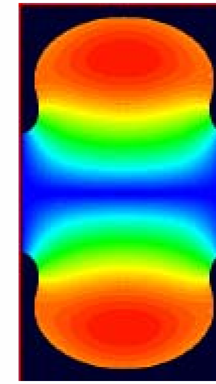
AC70 - Third EP Cavity in High Power Test





Relative Total Project Cost* (TPC) -vs- Linac Gradient





•TPC is for 500 GeV machine in US Options Study but does not include additional unpowered tunnel sections.

How to build a TeV LC ?

- Perform active R&D during ~10 Years
- Go international (↘cost, ↗effort) ICFA->ILCSC
- Create a large community of users -> ECFA in Europe + LCWS workshops
- Decide that the LC is the highest priority of HEP

-> Conclusion from ECFA after a wide consultation

- Get international recognition OCDE, EU
- Choose the best technology ITRP August 2004
- Join efforts to construct the best machine: Recent meeting at KeK
- Convince the scientific community, the public, the politicians -> outreach

ECFA OCDE

- Consultations ECFA organised in 2001 on the request of CERN and DESY directors

- Document ECFA (endorsed by the Consultative group OCDE and acknowledged by Ministers of Science in Jan 2004):

i) Exploiting the current frontier facilities until the contribution from these machines is surpassed by the results from the LHC or LC;

ii) Completing and then fully exploiting the LHC;

iii) Preparing for the approval of a Linear Collider of at least 400 GeV centre of mass energy, to run concurrently with the LHC in the decade starting in 2010;

iv) Supporting an appropriate R&D programme into novel accelerator designs (for very high energy electron-positron linear colliders, neutrino factories, muon colliders and very high energy hadron colliders).

A Community for the ILC

Euro Collaborations

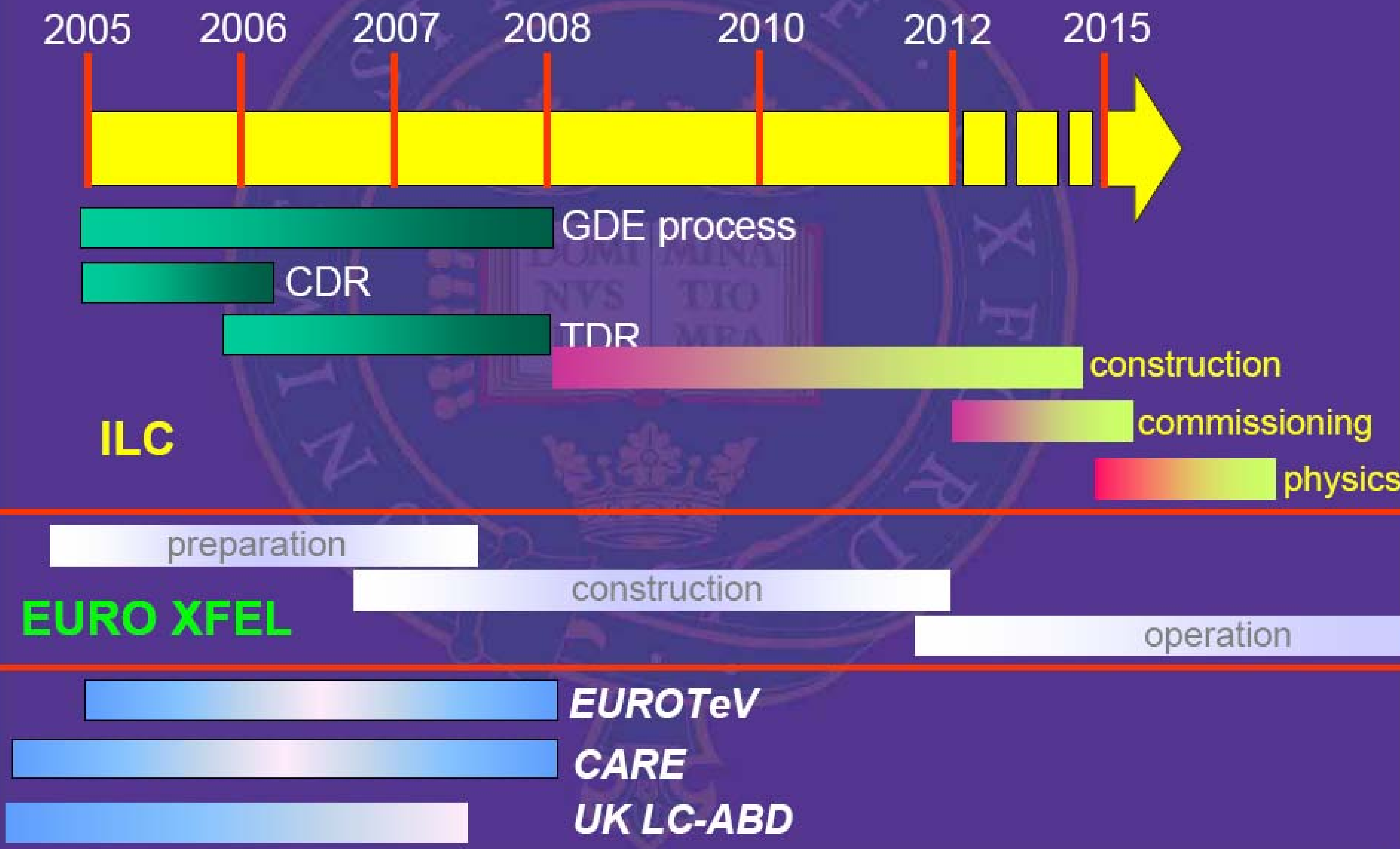
- TESLA (wider than Europe alone)
- European XFEL
- Coordinated Accelerator Research in Europe
- EuroTeV - LC research programme

EU Funded -> 2008

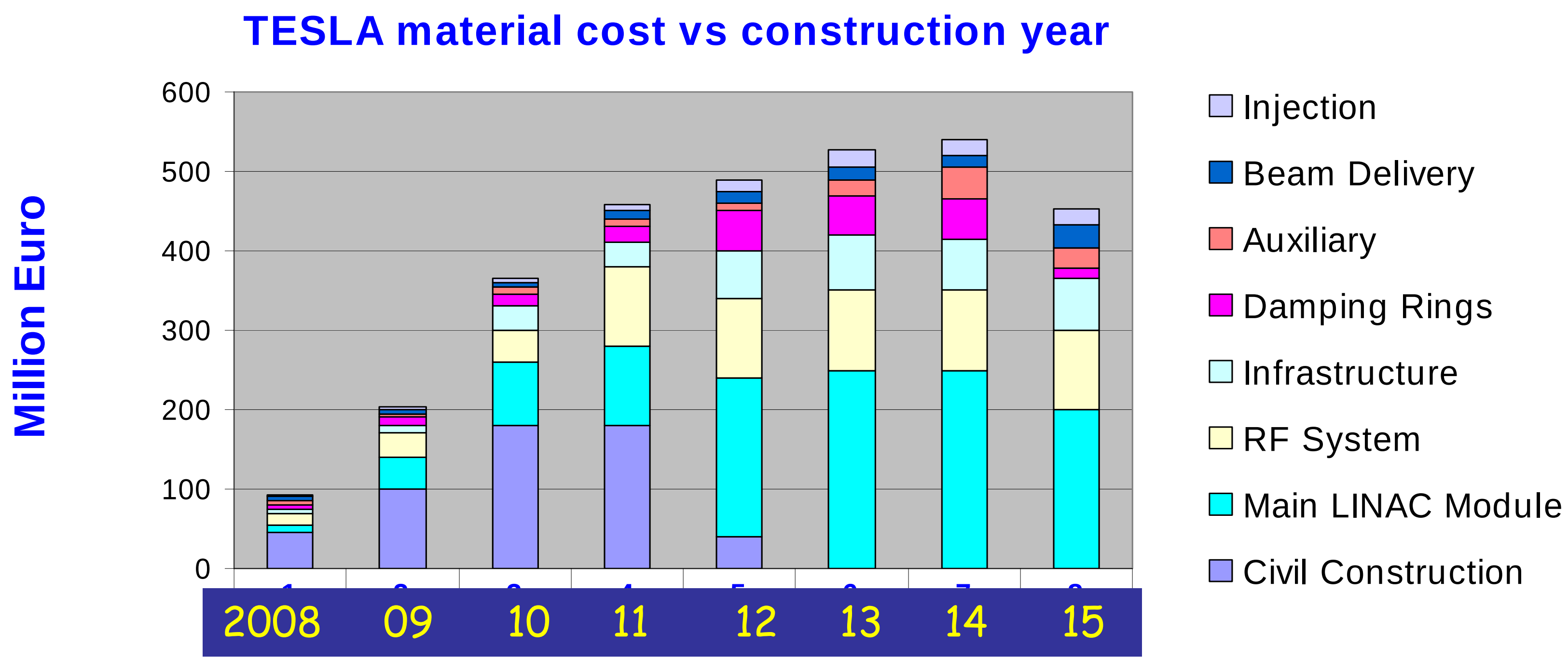
- UK Linear Collider Accelerator & Beam Delivery LCABD – PPARC & CCLRC-funded

Other funding via national agencies (i.e. many soruces)

Project Timelines



An exercise…..

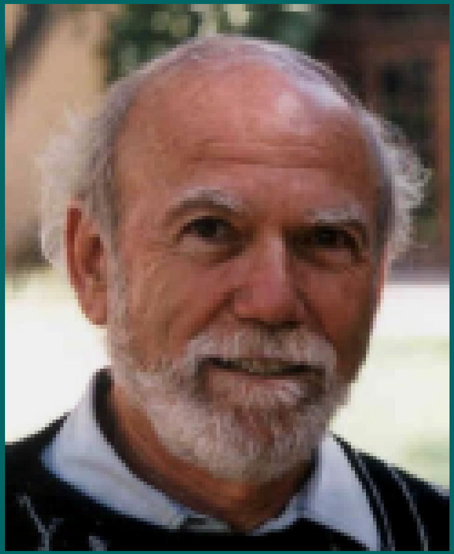


This is assuming a construction time of 8 years.

By parallel manufacturing of components this construction time can be shortened to ~ 6 years

-> matches turn on and first results of LHC before major spending starts

Our prioritization of the candidates was:



1. Barry Barish

2. Satoshi Ozaki

3. David Burke

Conclusions

- Physics arguments for a TeV ILC at very high luminosity are based on the Higgs sector
- There is no guarantee that new physics is directly observable at LHC/ILC
- LC can provide essential inputs, through PM, for indirect observations on new physics (Z')
- If light SUSY, ILC essential for accuracy (DM)
- The international process is continuously progressing and Europe has the SC technology (TTF, XFEL) well in hand and resources from EU
- I hope that Spain will become a major player in this fascinating enterprise

International Recognition for WW LC

Science, Technology and Innovation for the 21st Century Meeting of the OECD Committee for Scientific and Technological Policy at Ministerial Level, 29-30 January 2004 - Final Communique

They noted the **worldwide consensus of the scientific community, which has chosen an electron-positron linear collider** as the next accelerator-based facility to complement and expand on the discoveries that are likely to emerge from the Large Hadron Collider currently being built at CERN. They agreed that the planning and implementation of such a large, multi-year project should be carried out on a global basis, and should involve consultations among not just scientists, but also representatives of science funding agencies from interested countries. Accordingly, Ministers **endorsed the statement prepared by the OECD Global Science Forum Consultative Group on High-Energy Physics**:

A **roadmap** that identifies four interdependent priorities for global high-energy physics (HEP) facilities:

-The exploitation of current frontier facilities until contribution of these machines is surpassed

- Completion and full exploitation of the **Large Hadron Collider at CERN**

- Preparing for the development of a **next-generation electron-positron collider**

R1: R&D Needed for a Feasibility Demonstration of the Machine

R1 'Score Card': Is a Feasibility Demonstration Required* ?

	Modulators	Klystrons	RF Distribution	Accelerator Structures
TESLA	No	No	No	No (500 GeV) Yes (800 GeV)
NLC/JLC-X	No	No	Yes	Yes
JLC-C	No	No	Yes	Yes
CLIC	Yes	Yes	Yes	Yes

TABLE 2: Sumn

	TESLA		JLC-X/NLC[a]	
Center of mass energy [GeV]	500	800	500	1000
RF frequency of main linac [GHz])	1.3		11.4	
Design luminosity [10^{33} cm^{-2}s^{-1}]	34.0	58.0	25.0 (20.0)	25.0 (30.0
Linac repetition rate [Hz]	5	4	150 (120)	100 (120)
Number of particles/bunch at IP [10^{10}]	2	1.4	0.75	
$\gamma\varepsilon_x^*$ / $\gamma\varepsilon_y^*$ emit. at IP [m·rad × 10^{-6}]	10 / 0.03	8 / 0.015	3.6 / 0.04	
β_x^* / β_y^* at IP [mm]	15 / 0.40	15 / 0.40	8 / 0.11	13 / 0.11
σ_x^* / σ_y^* at IP [nm] before pinch[c]	554 / 5.0	392 / 2.8	2 243 / 3.0	219 / 2.1
σ_z^* at IP [μm]	300		110	
Number of bunches/pulse	2820	4886	192	
Bunch separation [nsec]	337	176	1.4	
Bunch train length [μsec]	950	860	0.267	
Beam power/beam [MW]	11.3	17.5	8.7 (6.9)	11.5 (13.8
Unloaded/loaded gradient[d] [MV/m]	23.8 / 23.8[e]	35 / 35	4 65 / 50	
Total number of klystrons	572	1212	4064	8256
Number of sections	20592	21816	12192	24768
Total two-linac length [km]	30	30	13.8	27.6
Total beam delivery length [km]	3		3.7	
Proposed site length [km]	33		32	
Total site AC power[f] [MW]	140	200	243 (195)	292 (350)
Tunnel configuration[g]	Single		Double	

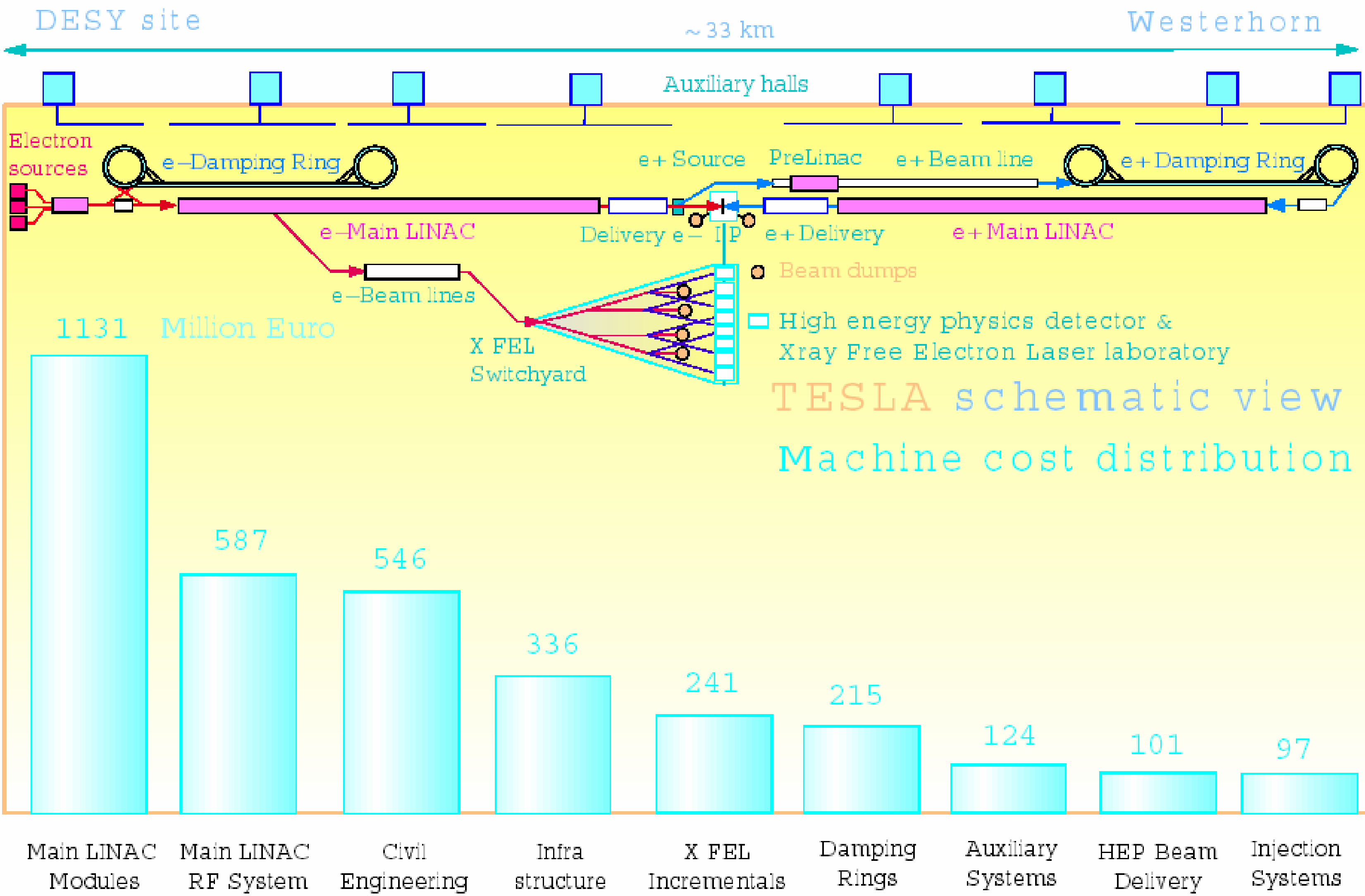


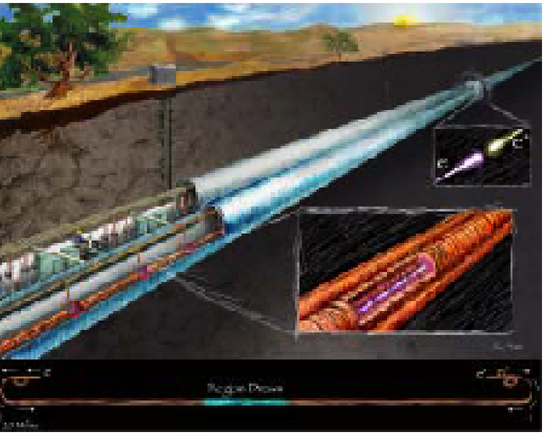
Figure 4.1.2: *Overview of the accelerator investment costs.*

3136 M€ for 500 GeV + 7000 person-year

Mid-Term Priorities

Priority: 13
Linear Collider

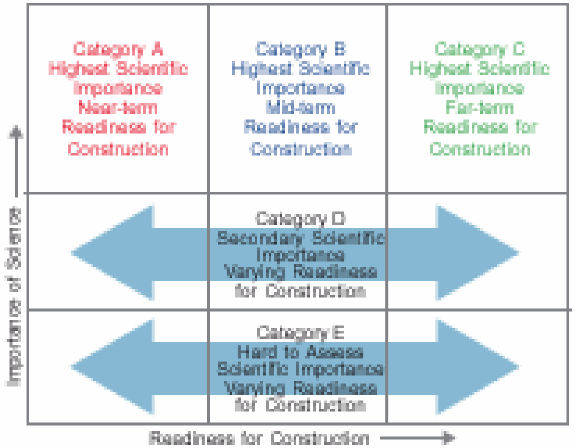
1st priority of Mid-Term



The Linear Collider is designed to extend the study of particle physics.

The Facility: The Linear Collider will allow physicists to make the world's most precise measurements of nature's most fundamental particles and forces at energies comparable to those of the Large Hadron Collider (LHC) now under construction in Switzerland.

Background: The Standard Model of particle physics, developed over the last 50 years and recognized as one of *the* great scientific achievements, has been tremendously effective in predicting the behavior of all the interactions of subatomic particles except those due to gravity, and in describing the varieties of particles that combine to make everyday matter. The next step—incorporating a theory of gravity and understanding why fundamental particles have mass—will require particle accelerators that function at the trillion-electron volt ("TeV") level.



Office of Science Facilities Matrix

physics world

2004
March
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Time for big decisions

Editorial: March 2004

Decisions taken this year will have a major impact on the shape of the global physics landscape for the next two decades. Discussions about the International Linear Collider (ILC) have just started in earnest and a decision on which technology to use is expected by the end of this year. Meanwhile, Japan and the EU are still trying to convince the other partners in the ITER fusion project of the relative merits of building the $5bn facility at Rokkasho-Mura and the French town of Cadarache.

A decision on ITER had been expected last December and again last month, but deadlock prevailed - as it has before. A decade ago the EU, Japan and US were unable to decide where to locate the ITER engineering-design activities, with the result that the work was split between Garching, Naka and La Jolla. There has been talk of something similar happening again - such as the tokamak and the control room being on different sites - but such a compromise should not be repeated.

A more meaningful consolation prize would be hosting IFMIF - an accelerator-based neutron source that will be used to check if materials are suitable for use in a fusion reactor. However, plans for IFMIF are still at an early stage, so it may not be available as the silver medal in the fusion Olympics. Logic dictates that ITER should be located an existing fusion lab, such as Cadarache, rather than at a green-field site like Rokkasho, but logic does not always prevail in such situations.

The ILC and ITER decisions are linked in that Japan is unlikely to be able to afford both - especially as it is already spending $1.5bn on the J-PARC accelerator complex. The US is not in the running to host ITER, even though the fusion experiment is the Department of Energy's (DOE) top near-term priority in its 20 year plan for new facilities. However, the US would like to host the linear collider, which is the highest mid-term priority for the DOE. This might explain American support for Japan as the site for ITER, although the US could also be extracting revenge for French opposition to the war in Iraq.

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Related links

ILC project

ITER

IFMIF

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Controlled fusion: the next step

EU backs France as ITER site

US maps fusion landscape

US rejoins ITER negotiations

Author
Peter Rodgers

D. Miller Detector issues 12/02/2004 ILCSC

3 concepts of Detector

Towards a Global DS

3 years R&D effort

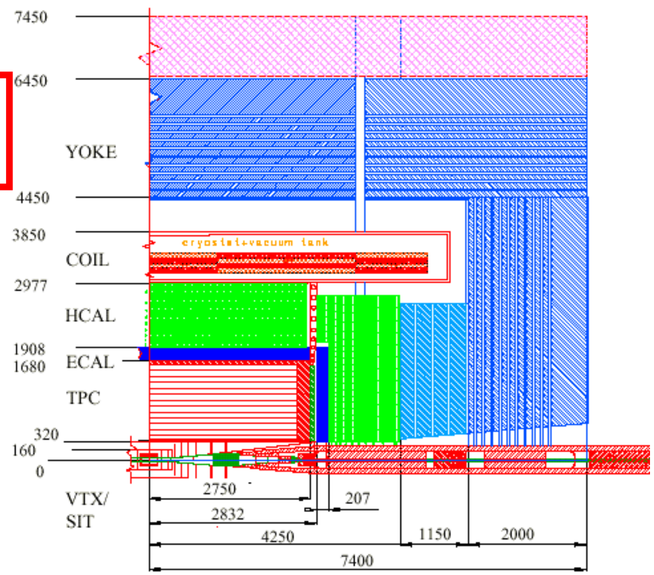
What has happened?
- Whole Detector Concepts

ILCSC

1. TESLA TDR
(N.A. "Large" similar)

Probably the most studied design (1, 8).
Rethink now starting.

Now has 4 T field
TPC tracker
CCD microvertex
Cal'rs inside 3m i.r. coil
SiW ECAL
Hermetic to 5 mr
Coil length 9.2m (c.f. CMS)



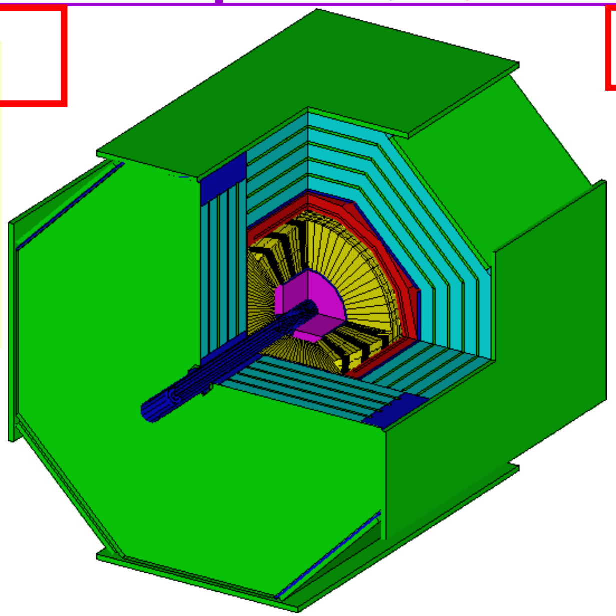
Whole Detector Concepts

ILCSC

2. GLC Detector (3)

Evolving from earlier JLC design.

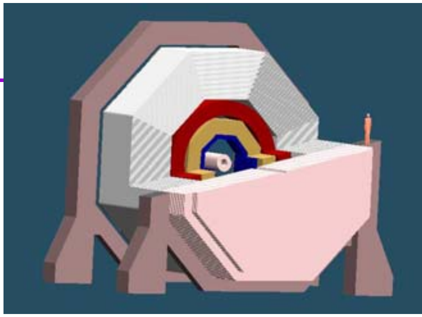
New 3 Tesla version
Jet-chamber tracker
Pb/scint ECAL+HCAL
inside 3.75m i.r. coil
Coil length 6.8m

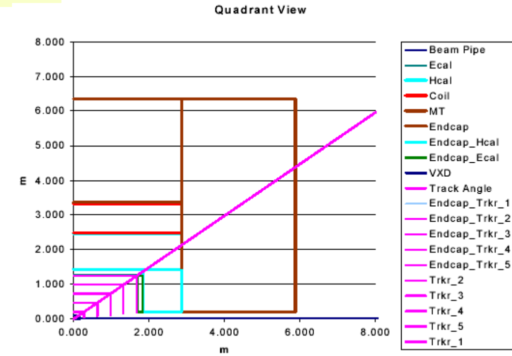


Whole Detector Concepts

3. North American SiD (4, 5, 6)

Always 5T
All silicon tracking; CCD + 5 layers of strips
Calorimeters inside 2.5m i.r. coil
Coil length 6m.
SiW ECAL





R&D programmes

ILCSC

(taken from WWS R&D website. http://blueox.uoregon.edu/~lc/randd.html
list incomplete – due for updates)

WWS keeping them in touch, encouraging co-operation between regions.

VERTEX DETECTOR

CCD
KEK-led collaboration
LCFI collaboration UK
Oregon/Yale Collaboration
Monolithic APS
Strasbourg-led collaboration
RAL-led collaboration
Hybrid APS
European collaboration
DEPFET
Bonn/MPI Group

MAIN TRACKER

TPC
Aachen, LBNL, MIT, DESY/U.Hamburg
Carleton/Montreal/Victoria, CERN
Orsay, Saclay, Wayne State, MPI-Munich,
Japan

Silicon
LPNE Paris, Santa Cruz, UCSC, Michigan,
Wayne State, SLAC, Asian groups

Jet Chamber
Asia

R&D programmes
(continued; *partial list*)

ILCSC

CALORIMETRY

SiW ECAL (+ HCAL)
CALICE, 28 Labs from 8 countries,
including Europe, US, Canada and Korea.
SiD, North America

Tiles etc.
Padova
KEK et al (GLC)

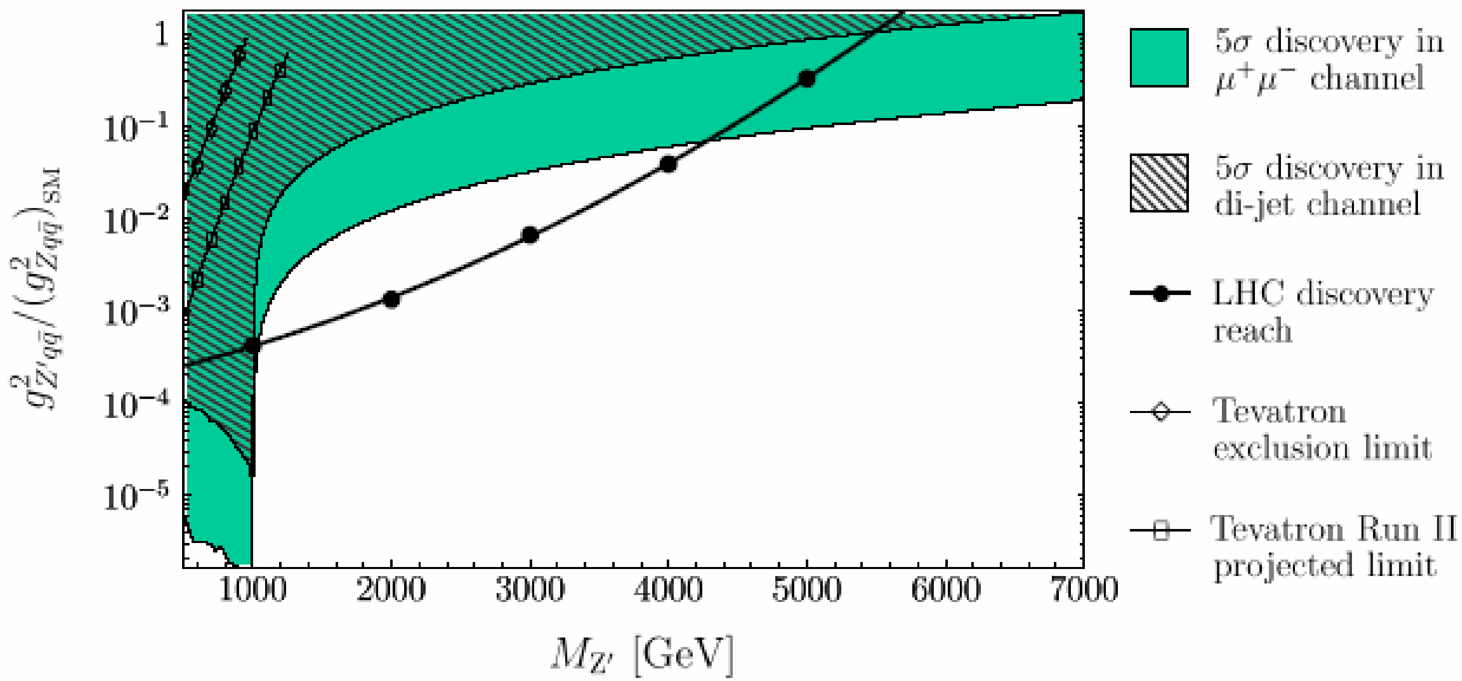
ALSO FORWARD DETECTORS
- MUON DETECTORS
- PARTICLE IDENTIFICATION
- TRIGGER+DATA ACQUISITION
- TEST BEAMS
- GAMMA GAMMA DETECTOR
- BEAMLINE INSTRUMENTATION

MOST R&D programmes are underfunded.

Not enough test beams available, especially with high energy hadrons.

Z’ at LHC/ILC

- Below 1 TeV gain for low coupling by Rad Return
- Above 5 TeV gain in mass with PM



A. Freitas hep-ph/0403288